CHEM 4804 Topics in Biochemistry: *Synthetic Biology*

The aim is to deepen the knowledge of biochemistry obtained in CHEM 2360 and CHEM 2370, and to promote the application potential of this knowledge by providing examples of cutting-edge bioengineering using Synthetic Biology (SynBio) principles.

Course Outline – 2020

Contact Information
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Course Information
MWF XX:XX - XX:XX p(a).m.
XXX Parker/Buller Building

Course Description

This course focuses on the current state of knowledge of the basic concepts, research areas and trends in synthetic biology (SynBio) - it aims at the (re-)design and fabrication of biological components and systems that do not already exist in the natural world. The focus will be on applied SynBio at the interface between chemistry, materials science, biochemistry, microbiology, biophysics, molecular & cell biology and engineering. Students will learn how to develop/re-program/redesign new processes (metabolism, translation, energy storage) using a variety of standardized and innovative methods. They will also expand and deepen their knowledge about enzymes, enzyme cascades, structural scaffolds and their application in industry and research, with a particular focus on sustainable biotechnology, biocatalysis, smart biomaterials, drug-delivery and environmental protection. The course aims to provide a basic familiarity with the most common SynBio topics and to understand the basic principles of synthetic cell design, which may be an important technology for an environmentally friendly and resource-saving bioeconomy.

Recommended Textbooks

Lehninger Principles of Biochemistry: International Edition, 7th edition, by Nelson, D. L. and Cox, M. M. Worth Publishers, 2017, ISBN-10: 9781319108243 (Available in Bookstore).

Evaluation

Mid-Term (30%):	50 min (written in class); date: t.b.d.
Final Exam (70%):	180 min; date: t.b.d.

There is no deferred midterm exam.

A medical certificate stating the reason for the missed exam must be presented within one week of the missed exam. This is valid for the midterm exam only. The final exam will be handled through Science and must be given within 48 hours of the final.

If a midterm examination is missed for a valid reason, the associated marks will be prorated onto the final examination. If no medical certificate is provided, the midterm grade will be 0%.

Mark Breakdown

A+	94-100%
A	85-93%
B+	75-84%
B	67-74%
C+	61-66%
C	51-60%
D	40-50%
F	0-40%

Academic Misconduct

It is up to the student to understand the rules of academic misconduct (cheating, plagiarism, etc.). Please refer to the University of Manitoba General Academic Regulations and Requirements, Section 7: Academic Integrity: (http://webapps.cc.umanitoba.ca/calendar10/regulations/).

Course Outline (Scripts: available via UMLearn for registered students only)

1. Introduction – what is life? Synthetic life as a technology?

Definitions and approaches to alternatives
Molecular and synthetic biology, engineering in biology
Biotechnological solutions to global world problems
The emerging bioeconomy for sustainable development

2. Life as chemical entity and energy flow

Choice of chemical elements for life: carbon vs. silicon
Chemical logic: Chemoton model and definition of life
Bringing evolution and bioenergetics together
Energy sources and chemiosmotic gradients

3. Strategies of energy storage and mobilization

"Making money of life" - universal strategy of ATP synthesis and regeneration
Fatty acids and glycogen: insulin, glucagon and adrenaline
Oxygen in biocatalysis and energy consumption: Monooxygenation and β-oxidation
Enzymatic glucose extraction from cellulose - concept of the biorefinery

4. Enzymes – molecular robots and catalysts

Stereochemistry, taxonomy and features of enzyme catalysis
Molecular memory & examples of enzymatic reactions
Ribozymes vs. Enzymes: case of CRISPR/Cas9
Cofactors in enzymatic reactions; cofactor regeneration

6. Protein folding and enzyme engineering & experimental evolution

Hierarchy of the globular protein structure organization
Alternatives to the "alanine world" – proteins based on glycine and proline backbones
Anfinsen dogma, basic folding principles, protein oxidation (aging)
Site directed mutagenesis & directed evolution of enzymes and cells

5. Biochemical transformation of substances and bioeconomy

Principles governing metabolic pathways – chemical logic
Metabolic engineering and novel synthetic pathways/routes
Established and emerging biotransformations
Biofuels and other sustainable energy sources

7. Flow of the genetic information and posttranslational events

Basics of replication, transcription and translation
Xeno-Nucleic acids (XNA) and 'Arsenic' life
XNA: Sugar and backbone modifications
Selection from the repertoire of Posttranslational Modifications (PTMs)

8. Basics of genetic code engineering

Views on the origins of biological coding
Genetic code: logic of its unity and organelle variations
Methods of genetic code engineering and expansion
Green fluorescent protein (GFP): classic and unnatural engineering

9. Proteins as machines and functional scaffolds

Preorganization principles & self-assembly on different scales
Silk, fibrin, elastin and collagen (vitamin C role)
Molecular machines: oxygen transport and muscle contraction
Engineering bioadhesion for bio-inspired materials sciences

Expected Outcome

Teaching of the above-mentioned contents and their theoretical foundations will take place through fontal lessons and blackboard exercises. Students will learn about the production of novel microbial syntheses of pharmaceuticals (biotransformations) and fine chemicals (biorefineries), the design and implementation of engineered (synthetic) cells for environmental protection and the sustainable development of the bioeconomy. The course aims to provide a basic understanding of all of these topics under the umbrella of Synthetic Biology as the most advanced bioengineering approach (dominated by the two main topics: "bottom-up" and "top-down" engineering approaches). The course is closely related to the International Genetically Engineered Machine (iGEM) competition on campus, which brings together students from different departments and faculties to conduct summer projects in synthetic biology. The course is suitable for biologists, biophysicists, immunologists, plant researchers, engineers and chemists as well as for anyone who wants to gain a good understanding of the basic principles of Synthetic Biology.